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The acoustic design of Outside Broadcast vehicles

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THE ACOUSTIC DESIGN OF OUTSIDE BROADCAST VEHICLES

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Summary

A review is given of the acoustic design of outside broadcast vehicles in terms of the constraints implicit in the use of road vehicles. A new design of vehicle wall construction is described, the provision of sound absorbing material suitable for use in small enclosures is discussed, and particular factors involved in utilising large (articulated) vehicles are mentioned. As an illustration, an account is given of the acoustic design of the BBC's Digital Control Vehicle: priority has been given, in this vehicle, to the provision of the best possible environment for sound monitoring and control.

Issued under the authority of

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THE ACOUSTIC DESIGN OF OUTSIDE BROADCAST VEHICLES

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1. Introduction

Although a few outside broadcast vehicles (mobile studios) are used by the BBC specifically for programme origination, the principal use of such vehicles is to to provide mobile control-room and production facilities for both the Sound and the Television services. In the latter case facilities are required for sound as well as for vision. It is frequently immaterial to the listener or viewer that the broadcast is in fact from an outside source, and the technical facilities provided should therefore be of as high a standard as is used at studio centres. This criterion is adopted as far as the programme-handling equipment is concerned. The acoustic environment within the sound-control areas should also in principle conform to the same standard as is provided in static control rooms, so that sound quality and balance may be equally accurately assessed and adjusted. Outside broadcast vehicles have, however, always been regarded as presenting a particularly severe problem in the field of acoustic design. Various factors contribute to the design difficulties, among which may be included: limitations of overall vehicle weight and size; priority which has to be given to operational requirements; suitability of materials for use in a vehicle; safety and health considerations.

This Report discusses outside broadcast vehicle design in terms of the constraints outlined above. Sound in any operational area falls into one of two categories: unwanted sound or 'noise' and wanted sound or 'programme', and it is convenient to discuss these two aspects separately.

2. Control of unwanted sound or 'noise'

2.1. Locally-generated noise

As in conventional studios and control rooms, noise in an outside broadcast vehicle may be due to local sources within the vehicle or to external noise transmitted through the enclosing surfaces. The ventilation system is probably the most important source of locally-generated noise, and conventional procedures may be applied to control it. Ducts and ports are however smaller than in conventional areas and the air velocity correspondingly higher, leading to increased turbulence. Ducts can be lined with absorbent material to attenuate ductborne sound but the duct lengths may be rather short for this technique to be fully effective. Full air-conditioning is usually provided in larger vehicles, and noise from the conditioning plant requires to be controlled. The main problem is the low-frequency noise generated by the pump driving the chiller unit. This may be separated from the chiller itself, fitted with anti-vibration mountings and sited outside the sound-insulating structure of the vehicle, but these steps do not usually provide sufficient isolation. On the basis that continuous noise is less disturbing than intermittent noise, the pump is allowed to run continuously and temperature control is provided by auxiliary heaters in the air flow.

Noise from technical equipment is exacerbated by the small size of the vehicle, as such items will be closer to the operator than in a conventional room. It is sometimes possible to place equipment to which limited access is required within a ventilated cupboard fitted with glass doors to permit observation of indicator lamps etc. This provides a useful degree of sound reduction. In a few cases (see Section 4.3) equipment may be placed in a separate compartment in the vehicle.

2.2. Sound insulation

The design of vehicle walls*, from the point of view of achieving adequate sound insulation, is subject to restrictions imposed by limitations on vehicle weight and size. Any reduction in the mass of the wall can be used to increase the load-carrying capacity of the vehicle (and therefore the permissible amount of technical equipment), while a reduction in wall thickness will increase the working space within it. Restriction of wall surface density (mass per unit area) will, on the other hand, limit the degree of sound insulation that can be achieved, while restriction of wall thickness precludes the use of double-leaf construction. Vehicle walls have to be thermally insulating as well as sound insulating and until recently it has been usual to accept the sound insulation provided by a thermally-insulating wall constructed of lightweight materials. Fig. 1 shows a typical construction of this type. New designs of vehicle wall have recently been developed (Fig. 2), particularly for use in constructing vehicles for monitoring and controlling sound programmes. For extra insulation a layer of sound insulation sheet or 'sound barrier mat' (a heavy

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* 'Wall' here includes all vehicle surfaces including the roof and floor.

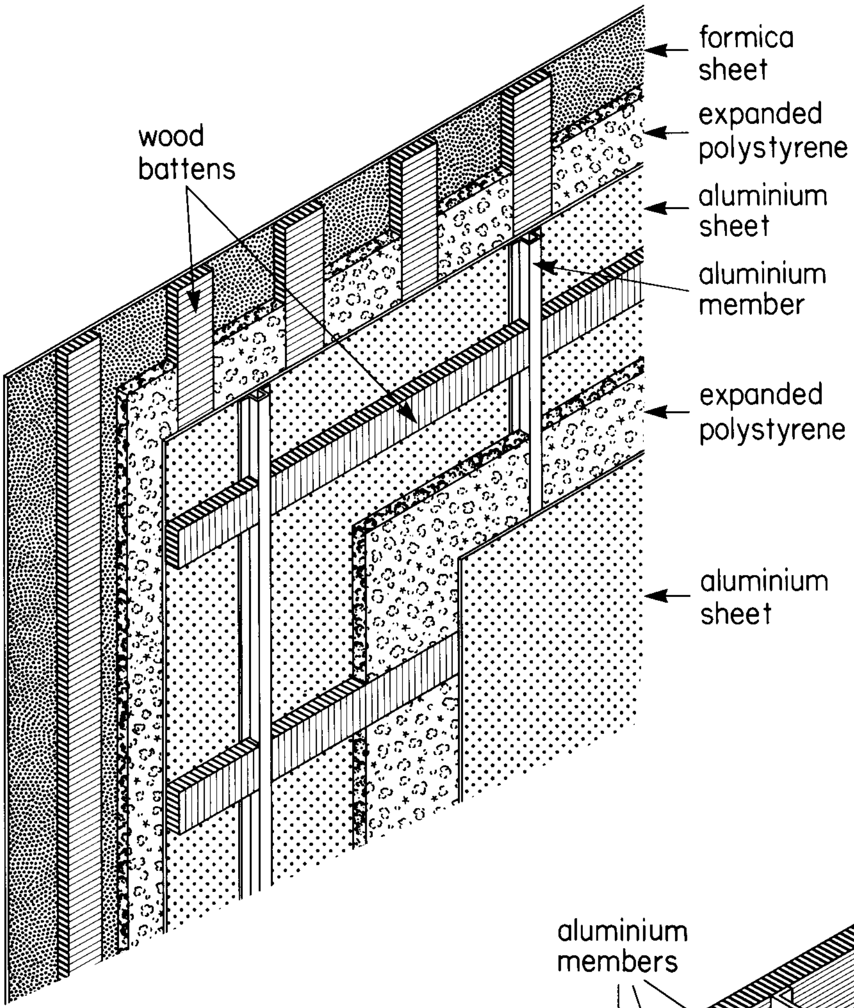

Fig. 1 – Old design of vehicle wall.

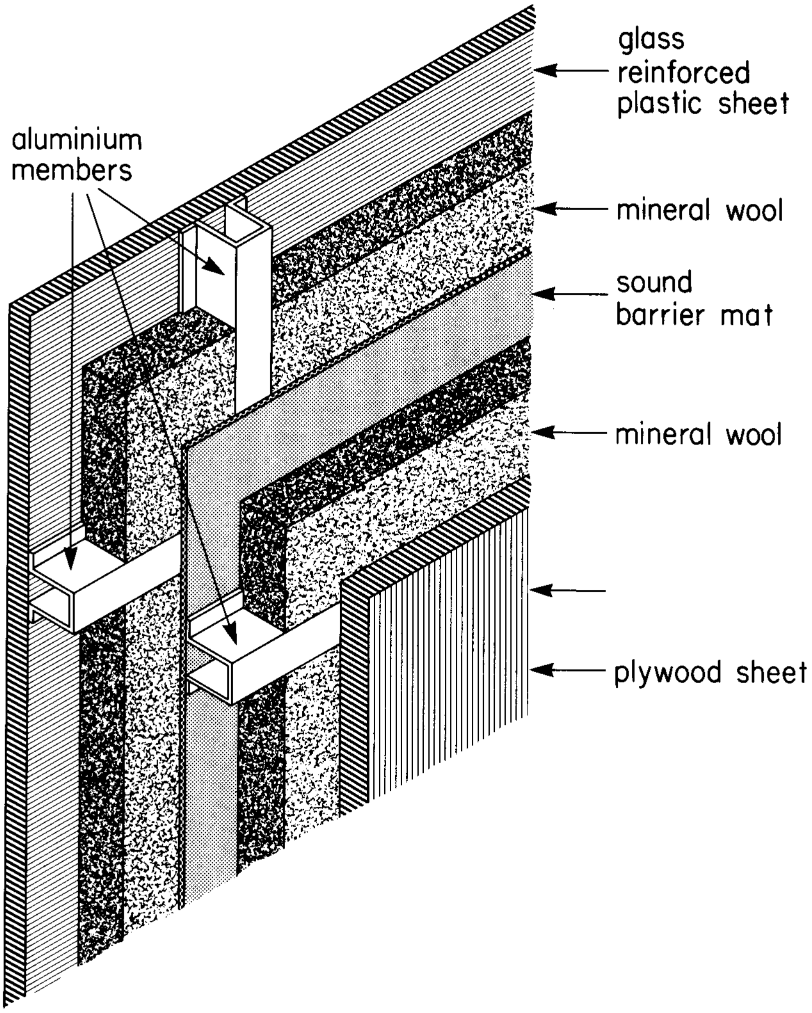

Fig. 2 – New design of vehicle wall.

flexible sheet of mineral-loaded plastic material on a fabric backing) can be added, as shown in the figure, although the surface density of the wall is increased as a result. Fig. 3 shows the typical insulation obtained using these two types of construction. About half the increase in sound insulation may be attributed to the increased surface density resulting from the inclusion of sound insulation sheet, the rest being caused by the different materials used in the two cases. Without the sound insulation sheet the surface densities of the two types of construction are approximately the same.

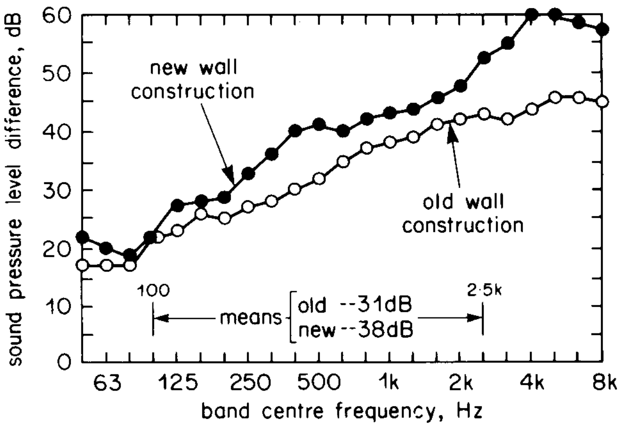

Fig. 3 – Comparison of sound insulation obtained with old and new types of wall construction.

Materials for use as infilling in wall construction have to be selected with some care[1]. There is for example a danger when using rigid foam for this purpose that a dip in insulation may occur in the mid-frequency range. The reason for this is that the compliance of the foam and the masses of the two cladding surfaces form a resonant system with an impedance lower than that normally provided by the overall surface density of the partition. Some damping may be provided by frictional effects if the foam is in the form of loose slabs, but the damping is reduced if the foam is bonded to the cladding surfaces. Fig. 4 shows an example of the sound insulation obtained using this type of construction.

Sound insulation at low frequencies always presents a problem in outside broadcast vehicle design, as it is not practicable to increase the wall surface density sufficiently to obtain a significantly higher insulation than is shown in Fig. 3. A problem that has recently come to light in this respect concerns the use of articulated vehicles (see Section 4.1) in outside broadcast work. For operational convenience it may be decided to construct the working space inside the trailer as one long 'room' rather than to split it into two or more interconnecting areas. An enclosure with one dimension much longer than the other two will have a very pronounced resonance at a low frequency (say about 25 Hz) which will be difficult to control with normal sound-absorbing techniques. Sound transmitted through the walls of the vehicle will excite this resonance, giving rise to a low-pitched 'rumble'. This can lead to a very tiring working environment especially if the level of sound outside the vehicle is high (for example, in the presence of heavy traffic noise). Where possible it is preferable to avoid such a method of construction, and to place at least one partition across the vehicle to mitigate the very low frequency resonance.

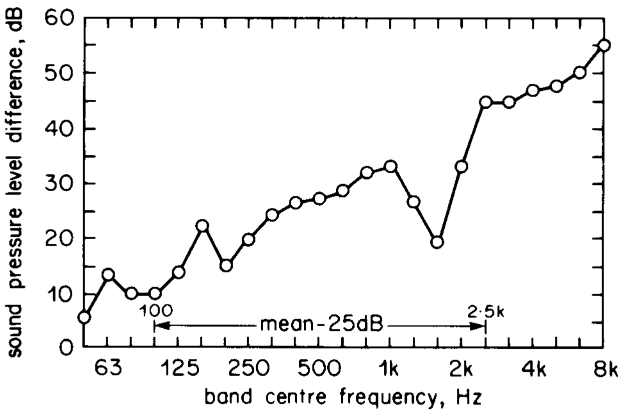

Fig. 4 – Sound insulation obtained with panel using rigid foam infill.

With new vehicle wall designs giving improved sound insulation, the avoidance of sound leakage paths assumes greater significance. Door seals are a particular problem and a double compression seal is usually provided. For safety reasons, however, door catches which rely on a lever running over a ramp ('meat-safe' catches) to compress the seal cannot be used. The door and its frame must therefore be of accurate and rigid construction for the seal to seat properly over its complete length under only moderate compression, and to remain effective for the life of the vehicle. Other precautions against sound leakage paths follow conventional studio practice: for example, the provision of double- or triple-glazed windows, blocking or 'pugging' cable ducts, and eliminating all unnecessary holes in the structure, however small.

3. Control of wanted sound or 'programme'

3.1. The acoustic environment

Following conventional studio design practice calculations of sound absorption inside a vehicle can in principle be made in order to achieve a reverberation time characteristic consistent with good listening conditions. A design reverberation time from 250 Hz upwards of 0.2 sec. is used, but the characteristic actually achieved depends on the limitations of absorber area, dispostion and type which are imposed by the small size of the enclosures under consideration, and also the requirements of individual vehicles (the amount of wall-mounted equipment, for example). The small enclosure size is of particular importance in the lower frequency ranges. In the first place, the effect of room modes (eigentones) must be considered[2]. Although for any room the number of modes in a given one-third octave frequency band increases with the band centre frequency, the number of modes in a band of particular centre frequency becomes smaller with a decrease in the size of the room (Fig. 5). In a small vehicle enclosure the frequency range where the room modes are rather widely spaced in frequency is higher than in the case of a larger static control room. The consequent variation of reverberation time and sound quality from place to place in the room is therefore correspondingly more audible, making a satisfactory overall characteristic more difficult to achieve. In the second place, restrictions in space inside a vehicle often preclude the provision of effective but bulky low-frequency absorbers. Inadequate low-frequency absorption gives rise to a corresponding exaggeration of sound level and lengthening of reverberation time. An additional factor which exacerbates the room acoustic irregularities in outside broadcast vehicles, again caused by the small enclosure size, is that the loudspeakers may have to be nearer to the walls than in a static control room. Objective equalisation of the loudspeaker signals, so as to produce a flat frequency response at the sound control position, leads to equalisation characteristics which are very irregular in character, the response in adjacent one-third octave bands sometimes differing very considerably. Furthermore, such objective equalisation usually leads to different characteristics being required for the left-hand and right-hand loudspeakers. In the BBC's experience this equalisation procedure has always given rise to unsatisfactory subjective sound quality, particularly when this is judged on such critical programme material as speech. A more satisfactory result has been obtained by using loudspeaker equalisation based on a subjective assessment of sound quality at the control position. Such equalisation usually consists of a smooth 'bass-cut' characteristic, typically providing about 10 dB of attenuation at 50 Hz, with a slope of about four decibels per octave. In addition one or two shallow notches may be provided at higher frequencies, to reduce sound colorations caused by specular reflections.

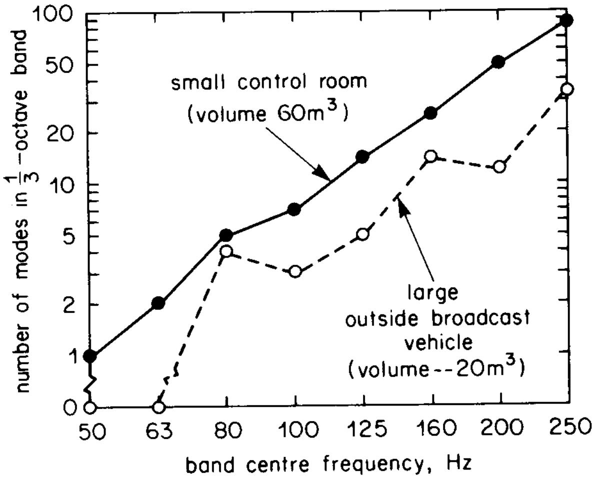

Fig. 5 — Room modes in static and vehicular control rooms.

3.2. Sound absorbers

Until recently the principal method used to obtain controlled sound absorption in a vehicle was by the use of absorbing material covered by perforated rigid panels, the overall absorption in such cases being an average of the amounts taking place through the holes and at the panel surface. In fact, sound absorption takes place largely through the holes and the characteristics of such acoustic treatment therefore depend, among other factors, on their diameter and spacing. This technique works well in conventionally-sized studios and control rooms, and indeed remains a very important method of sound control. Near to such absorbers, however, reflections from the hard panel can produce an 'edgy' or 'tinny' sound quality. In a vehicle, walls and ceiling may be within about one metre (three feet) of the sound control position, and this defect in sound quality can become very apparent. In current vehicle design, therefore, such hard surface treatment is confined as far as possible to areas where it will not cause direct specular reflections from known sound sources (the loudspeakers in particular). Parts of the ceiling, and wall areas below sitting ear-height, represent convenient sites for this treatment. Surfaces within the vehicle from which troublesome specular reflection could occur are covered with material having sound-absorbing characteristics which do not rely on 'averaging' between areas of high and low absorption. Conventional all-wool Wilton carpet (without underlay) has been found to be very suitable in this respect, and its use has the additional benefit of providing a visually attractive and hard-wearing finish to the walls of the vehicle. The ceiling area over and in front of the control position is also carpet-covered, for specular reflection control.

4. The Digital Control Vehicle

4.1. Use of articulated vehicles

Until recently the BBC has avoided the use of articulated vehicles for general outside broadcast use, principally because the high mobility required of all outside broadcast vehicles implies that almost as many towing vehicles as trailers would be required, leading to considerable extra expense. Recently, however, such vehicles have been constructed, principally in cases where a vehicle to fulfil a particular specialist requirement is involved. The benefit to be gained from the use of an articulated vehicle is the very considerable relaxation in size (particularly length) and weight constrictions, as compared with rigid-chassis vehicles, giving greater freedom to achieve a good acoustic design. A good example of this technique is the BBC's 'Digital Control Vehicle' which has been built to house the digital sound mixing desk designed and built by Neve in collaboration with the BBC. Fig. 6 shows a general view of this vehicle. The picture was taken at an early stage of fitting-out the vehicle, when the air-conditioning compressor units were not in position. These fit into the empty compartment seen at the forward end of the vehicle, on the left of the picture. Two aspects of the acoustic design of this vehicle which are of particular interest are discussed in Sections 4.2 and 4.3.

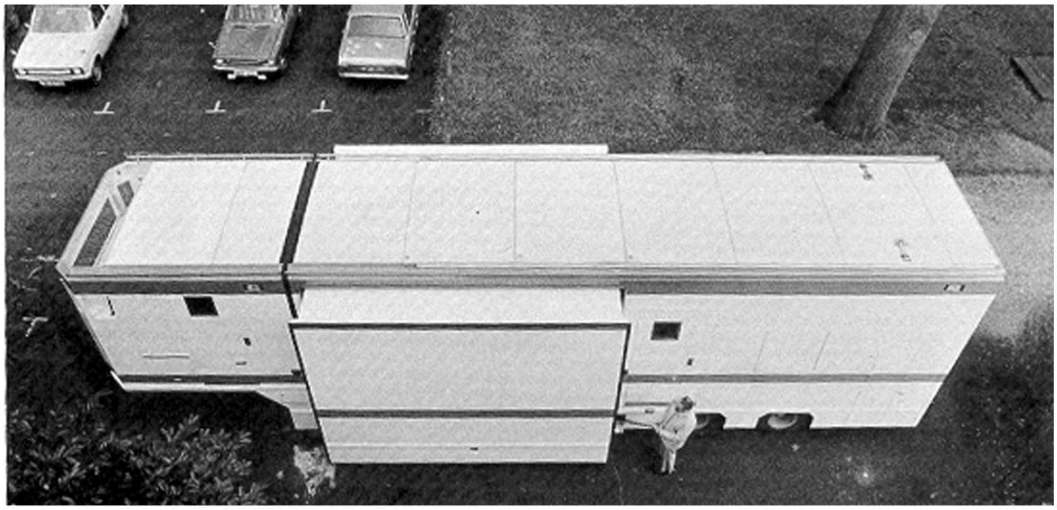

Fig. 6 — Exterior of Digital Control Vehicle.

4.2. Control-area acoustics

The size of the control room in the Digital Control Vehicle has been increased, relative to the size more usually found in outside-broadcast vehicles, in two ways. In the first place, advantage has been taken of the extra length which is available using an articulated vehicle, without however involving the danger of low-frequency resonance (see Section 2.2). Secondly, the sides of the control room have been constructed to extend outwards (Fig. 7): this increases the volume of the enclosure from about $20m^3$ to about $30m^3$. The movement of the sides is effected by hydraulic rams mounted under the floor of the vehicle, controlled by a small hand-held unit as can be seen in Fig. 4. Compression seals are fitted round the edges of the extending sides and these are effective when the sides are fully extended or fully retracted. The resulting enclosure is still small compared with a static control area, but the increase in volume which has been achieved has resulted in a very worthwhile improvement in sound quality. Some of the increased space available has been used to provide more effective low-frequency treatment[3]: most of this is placed on the side walls, but some is placed on an end wall and on the ceiling, to control room modes more effectively. During tests made in the empty (unequipped) control area it was not found necessary to provide low-frequency loudspeaker equalisation, as described in Section 3.1, although some correction to reduce sound coloration was then found to be useful. The need for this correction will however be re-assessed when the installation of the equipment has been completed. In fact, the vehicle can be used with the sides retracted as well as extended, and it has been found possible to place the loudspeakers very close to the side walls under these conditions, without too much degradation of sound quality. Specially-

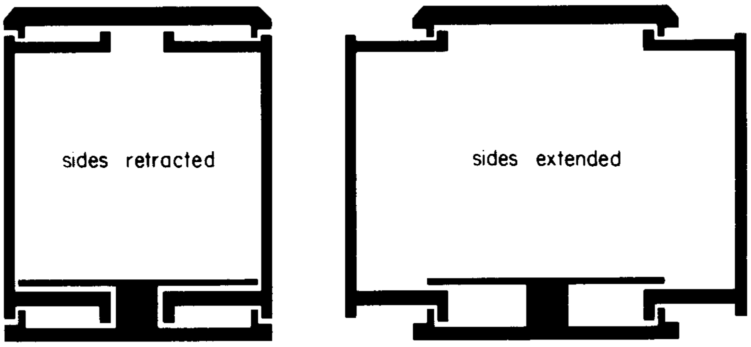

Fig. 7 – Cross-sectional view of extending sides of Digital Control Vehicle.

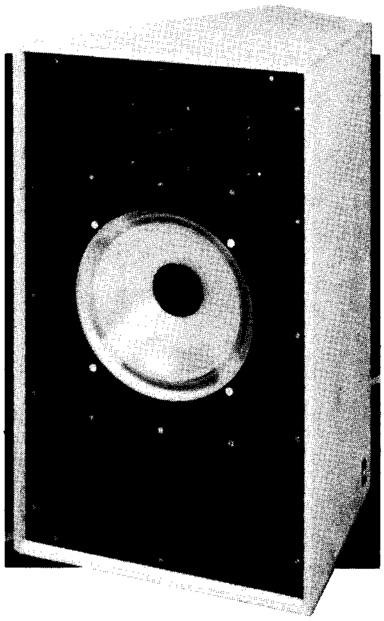

Fig. 8 – Loudspeaker for use in Digital Control Vehicle.

shaped loudspeaker cabinets (Fig. 8) are used to take maximum advantage of this capability. This technique enables a wider stereophonic sound-stage to be obtained, compared with the conditions normally applying in outside broadcast vehicles. Figs. 9 and 10 show the control room of the Digital Control Vehicle with the sides extended and retracted respectively. These pictures were taken before the mixing desk had been installed. Most of the wide-band acoustic treatment, effective at lower frequencies than is usual in an outside broadcast vehicle, is behind the panels on each side wall. The additional wide-band units can be seen on the end wall (behind the television monitor) and on the ceiling between the rows of lights.

4.3. Sound insulation

The relaxation in the size and weight limitations that follow from the use of an articulated vehicle (see Section 4.1) has enabled the Digital Control Vehicle to be constructed using a wall of thicker cross-section than is normal in an outside broadcast vehicle. Fig. 11 shows the insulation obtained with the sides of the vehicle extended and retracted. The average insulation under the second of these conditions is excellent for a vehicle: the wall panels must still, however, be regarded as "lightweight" in acoustical terms and the amount of low-frequency insulation is therefore still rather small for the reasons discussed in Section 2.2. The lower insulation performance obtained with the sides extended is caused by the seals atound the expanding sides being less effective under these conditions, and the greater area of wall exposed to ambient external sound. Nevertheless, the insulation is still comparable with that obtained in present-day conventional vehicles which make use of the new vehicle wall designs outlined in Section 2.2, as can be seen by comparing Fig. 11 with Fig. 3.

The digital mixing desk involves signal-processing equipment having considerable power dissipation, and therefore requiring forced-air cooling. In order to protect the sound-control area from the resulting cooling-fan noise, the vehicle has been constructed as two separate cabs on the same chassis (Fig. 12). The smaller cab houses the signal-processing equipment. The only connection to the rest of the vehicle is through an underfloor cable duct, which is thoroughly pugged to eliminate sound leakage. The insulation achieved between the equipment and control areas is shown in Fig. 13. Since in this case the two areas are effectively separated by a two-leaf wall construction, it is possible to examine the additional insulation that could be obtained in a vehicle, using this method of wall construction, by comparing the results shown in Fig. 13 with those obtained using single-leaf construction (Fig. 11, dashed curve). Allowances must be made for the different partition areas in the two cases and also for the presence of a diffuse sound field on the source side of the panel in the case of the two-leaf measurements (Fig. 13) and a direct sound field in the case of the single-leaf measurements (Fig. 11). Both of these factors would tend

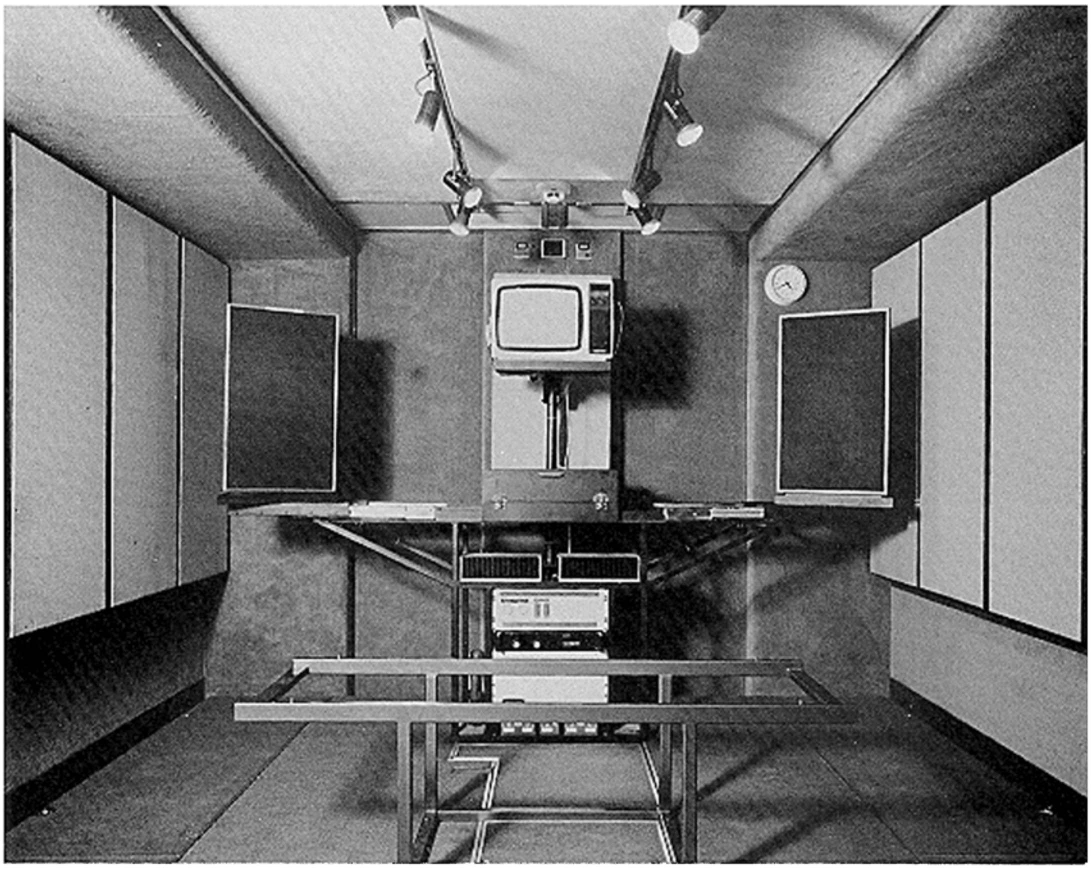

Fig. 9 — Control room of Digital Control Vehicle : sides extended.

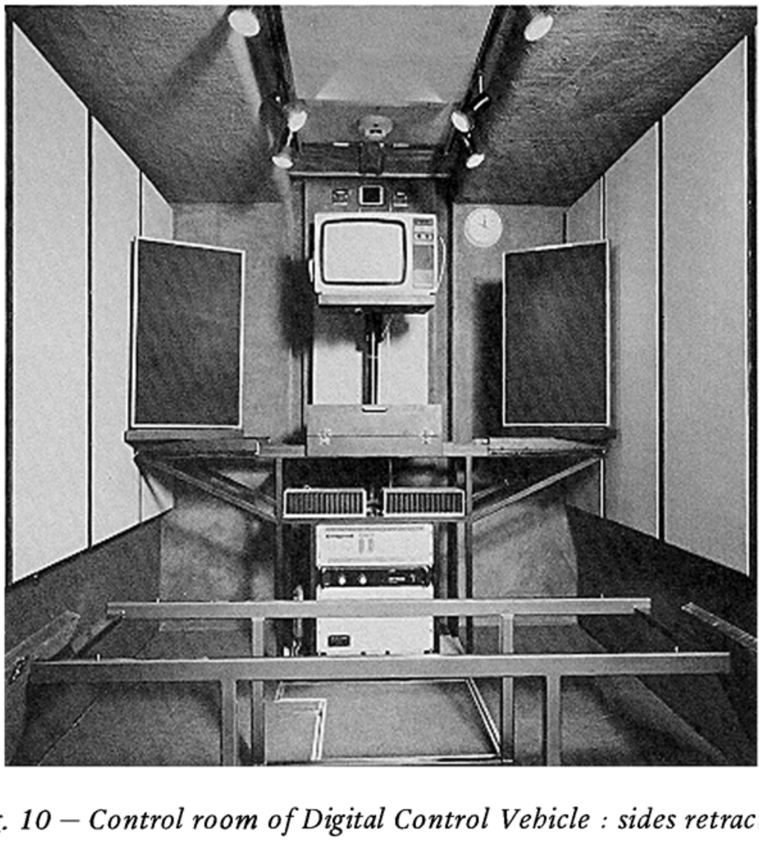

Fig. 10 — Control room of Digital Control Vehicle : sides retracted.

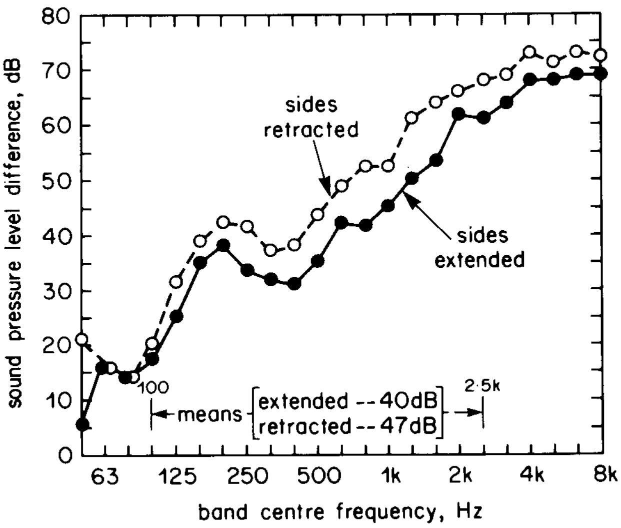

Fig. 11 – Sound insulation of Digital Control Vehicle with sides extended and retracted.

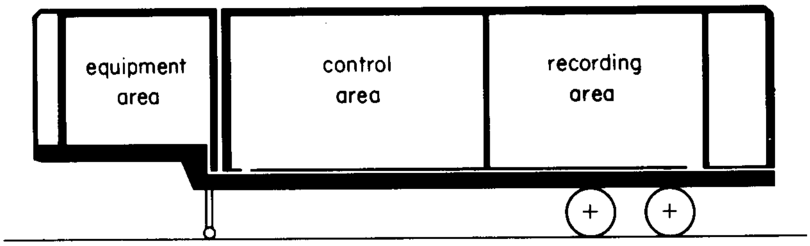

Fig. 12 – Two-cab construction of Digital Control Vehicle.

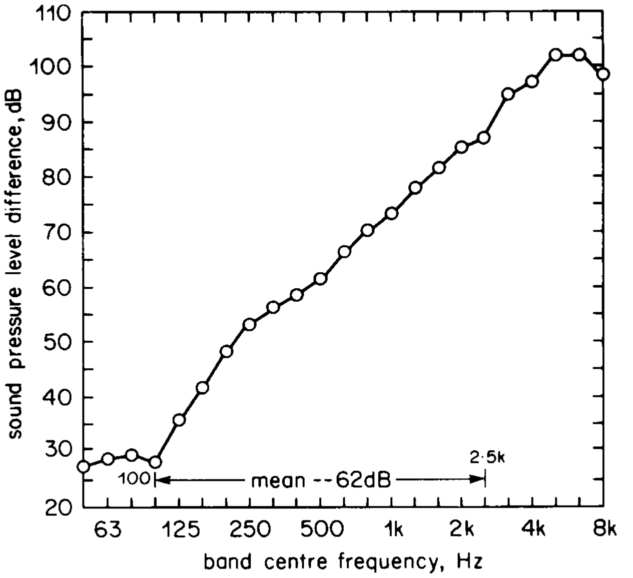

Fig. 13 – Sound insulation between equipment and control areas of Digital Control Vehicle.

to enhance the two-leaf insulation measurements. Allowing, somewhat arbitrarily, 8 dB for these factors (2 dB for the area difference and 6 dB for the sound-field factor[1]), the improvement in insulation obtained in a two-leaf construction is on average about 14 dB above 320 Hz but falls to zero (again on average) at lower frequencies. This low-frequency performance is not surprising, for two reasons. In the first place, the two-leaf method of construction is ineffective at low frequencies when the leaf separation is very small compared with the sound wavelength. Under these conditions the two leaves are coupled together by the compliance of the air between them and act as a single leaf having twice the surface density of the individual panels. The most that can be expected under these conditions is an insulation increase due to the higher overall panel surface density (i.e. 6 dB). Additionally, there is structure-borne leakage through the common chassis on which the two cabs are built. This latter effect could have been reduced by mounting the smaller cab on anti-vibration mountings but the extra complication and expense was not considered worthwhile.

Problems concerned with isolation from noise generated by the air-conditioning compressors have been discussed in Section 2.1. In the Digital Control vehicle the compressors are mounted forward of the equipment area and outside the sound-insulating structure. In this way three sound-insulating walls are interposed between the compressors themselves and the control room: structure-borne noise is reduced by the use of anti-vibration mountings for the compressors.

5. Conclusions

Legal restrictions on vehicle weight and size contribute to the difficulties of acoustic design of the working environment inside an outside broadcast vehicle. Only relatively lightweight materials can be used in the construction of the bodywork, leading to limitations on the sound insulation (particularly at low frequencies) which can be achieved between the exterior and interior of the vehicle. Improved sound insulation has been achieved by using a new design of vehicle wall. The small size of the enclosures inside the vehicle give rise to a pattern of room resonances which can lead to significant sound coloration and variation of the sound quality from position to position. Furthermore, control of the sound quality at low frequencies is difficult to achieve because of the lack of space for bulky low-frequency sound absorbers. An acceptable working environment for sound monitoring and control may nevertheless be created inside an outside broadcast vehicle by careful choice of materials and methods of construction. The use of articulated vehicles relaxes the legal size and weight restrictions to some extent and therefore eases the acoustic design problem. A further improvement in the sound quality obtained inside a vehicle may be made by arranging for the walls of the vehicle to extend outwards, thus increasing the volume of the working space. These two expedients have been adopted in the case of the Digital Control Vehicle, in which a very satisfactory environment for sound monitoring has been obtained. Isolation of noise from technical equipment has been achieved in this vehicle by constructing equipment and control/ recording areas as two separate cabs on a common chassis.

6. References

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